

We Claim:

1. A process for producing aliphatic 1,3-diols which comprises:

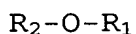
- a) Contacting at a temperature within the range from about 30 to about 150°C and a pressure within the range of about 3 to about 25 MPa, an oxirane, carbon monoxide, and hydrogen, in an essentially non-water-miscible solvent in the presence of an effective amount of a homogeneous bimetallic hydroformylation catalyst comprising a cobalt carbonyl compound and a cocatalyst metal which is selected from the group consisting of ruthenium, copper, platinum, and palladium, and which is ligated with a ligand selected from the group consisting of a phosphine ligand, a bidentate or multidentate N-heterocyclic ligand, a porphorine ligand, and a phospholanoalkane ligand, optionally in the presence of a promoter, wherein the molar ratio of ligand to cocatalyst metal atom is in the range of about 0.2 :1.0 to about 0.6:1.0, under reaction conditions effective to produce a reaction product mixture containing an aliphatic 1,3-diol;
- b) Adding an aqueous liquid to said reaction product mixture and extracting into said aqueous liquid a major portion of the aliphatic 1,3-diol at a temperature less than about 100°C to provide an aqueous phase comprising the aliphatic 1,3-diol in greater concentration than the concentration of the aliphatic 1,3-diol in the reaction product mixture and an organic phase comprising at least a portion of the bimetallic hydroformylation catalyst;
- c) Separating the aqueous phase from the organic phase; and

- d) Optionally returning at least a portion of the organic phase containing catalyst to step (a).
2. The process of Claim 1 wherein the cobalt carbonyl compound is an essentially nonligated cobalt carbonyl compound.
  3. The process of Claim 1 wherein the oxirane is ethylene oxide.
  4. The process of Claim 1 wherein the aqueous liquid is water.
  5. The process of Claim 1 wherein the aliphatic 1,3-diol is 1,3-propanediol.
  6. The process of Claim 1 wherein the extraction of step (b) is carried out at a temperature of about 5 to about 90°C.
  7. The process of Claim 6 wherein the extraction is carried out at a temperature of about 25 to about 55°C.
  8. The process of Claim 1 wherein the extraction is carried out under carbon monoxide atmosphere.
  9. The process of Claim 8 wherein the extraction is carried out under about 0.3 to about 5 MPa of carbon monoxide at about 25 to about about 55°C.
  10. The process of Claim 1 wherein the oxirane concentration is not less than about 0.2% by weight.
  11. The process of Claim 10 wherein the oxirane concentration is from about 0.2 to about 20% by weight.
  12. The process of Claim 11 wherein the oxirane concentration is from about 0.2 to about 10% by weight.
  13. The process of Claim 1 wherein the temperature in step (a) is in the range of about 50 to about 125°C.
  14. The process of Claim 13 wherein the temperature is in the range of about 60 to about 110°C.
  15. The process of Claim 1 wherein the pressure in step (a) is in the range of about 5 to about 15 MPa.

16. The process of Claim 15 wherein the pressure is in the range of about 7 to about 12 MPa.

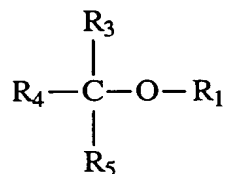
17. The process of Claim 1 wherein the cocatalyst metal is ruthenium.

18. The process of Claim 1 wherein solvent is selected from the group consisting of alcohols and ethers described by the formula:



where  $R_1$  is hydrogen or  $C_{1-20}$  linear, branched, cyclic, or aromatic hydrocarbyl or mono- or polyalkylene oxide and  $R_2$  is  $C_{1-20}$  linear, branched, cyclic or aromatic hydrocarbyl, alkoxy or mono- or polyalkylene oxide.

19. The process of Claim 1 wherein the solvent is selected from the group consisting of solvents described by the formula:

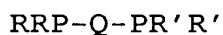


wherein  $R_1$  is hydrogen or  $C_{1-8}$  hydrocarbyl and  $R_3$ ,  $R_4$ , and  $R_5$  are independently selected from  $C_{1-8}$  hydrocarbyl, alkoxy, or alkylene oxide.

20. The process of Claim 1 wherein the solvent is selected from the group consisting of methyl-t-butyl ether, ethyl-t-butyl ether, diethyl ether, phenylisobutyl ether, ethoxyethyl ether, diphenyl ether, and diisopropyl ether.

21. The process of Claim 1 wherein the phosphine ligand is a ditertiary phosphine ligand.

22. The process of Claim 21 wherein the ditertiary phosphine ligand is selected from the group consisting of phosphines of the general formula:



wherein each group  $R$  and  $R'$  independently or jointly is a

hydrocarbon moiety of up to 30 carbon atoms, and Q is an organic bridging group of 2 to 4 atoms in length.

23. The process of Claim 1 wherein the ligand is a N-heterocycle selected from the group consisting of 2,2'-dipyridyl, 2,2'-bipyrimidine, and 2,4,6-tripyridyl-s-triazine.

24. The process of Claim 1 wherein the ligand is a phospholanoalkane selected from the group consisting of 1,2-bis[(2R, 5R)-2,5-dimethylphospholano]ethane, 1,2-bis[(2S, 5S)-2,5-dimethylphospholano]ethane, a racemic mixture of the two, and 1,2 bis (phospholano) ethane.

25. The process of Claim 1 wherein the ligand is a porphorine selected from the group consisting of octaethylporphorines and tetraphenylporphorines.

26. The process of Claim 1 wherein the ligand to cocatalyst metal molar ratio is in the range of about 0.20:1.0 to about 0.40:1.0.

27. The process of Claim 1 wherein a promoter is used and it is lipophilic.

28. The process of Claim 27 wherein the lipophilic promoter is selected from the group consisting of quaternary ammonium or phosphonium salts, lipophilic amines, lipophilic arsines, and lipophilic phosphine oxides.

29. The process of Claim 1 further comprising extracting residual catalyst from the aqueous phase and returning said residual catalyst to step (a).

30. The process of Claim 1 wherein at least a portion of the organic phase containing catalyst is returned to step (a).

31. The process of Claim 1 wherein the cocatalyst metal to cobalt molar ratio is at least about 0.05:1.

32. The process of Claim 31 wherein the cocatalyst metal to cobalt molar ratio is from about 1:1 to about 1:2.

33. A catalyst composition for the hydroformylation of ethylene oxide to 1,3-PDO prepared by a process comprising:

- a) forming a complex (A) by contacting a cocatalyst metal compound, which is selected from the group consisting of ruthenium, copper, platinum, and palladium compounds, with a ligand, wherein the molar ratio of ligand to cocatalyst metal atom is in the range of about 0.2:1.0 to about 0.4:1.0;
- b) forming a complex (B) by subjecting complex (A) to a redox reaction with a cobalt compound.

34. The composition of Claim 33 wherein the cobalt compound is an essentially nonligated cobalt carbonyl compound.

35. The composition of Claim 33 wherein the ligand is selected from the group consisting of a phosphine ligand, a bidentate or multidentate N-heterocyclic ligand, a porphorine ligand, and a phospholanoalkane ligand.

36. The composition of Claim 33 wherein the cocatalyst metal is ruthenium.